cessive additions reach the third or some higher term, and also if the sum added to $16n^2+8n$ be equal to the term with which the operation commenced, it is contended the following term may be attained, and so on, and every number of the form $8n+4$ will be composed of 4 odd squares. The paper concludes by a suggestion that the method is applicable to several other similar problems.

2. "On the Valves of the Heart." By W. Savory, Esq. Communicated by Edward Stanley, Esq., F.R.S. Received September 30, 1852.

The paper contains observations upon the structure and connections of the auriculo-ventricular and arterial valves of the human heart, which the author thinks will assist in explaining their nature and functions.

The relation of the "four orifices" in the base of the heart is examined, and it is shown that the aortic and left auriculo-ventricular apertures are not separated as the others are; that no muscular tissue of the ventricle intervenes between them, but that when the auricles and great vessels are separated from the ventricles (which may be accomplished with facility after prolonged boiling), the aortic aperture is separated from the left auriculo-ventricular only by the anterior mitral valve; and when this is removed (or even while it remains), it is plainly seen that only one aperture exists whose borders are formed by the muscular tissue of the ventricle, and in shape somewhat resembling the figure 8. This is divided into two portions, an anterior (aortic) and posterior (auriculo-ventricular) by the anterior mitral valve, and above it, by the posterior wall of the aorta, into which is inserted a large portion of the anterior wall of the left auricle, but no muscular tissue of the ventricle intervenes.

When the auricles and vessels are removed, it is seen that the three orifices are bounded by thick and convex borders formed by the bases of the ventricles. Those on the left side are broadest; the difference between the two sides corresponding with the difference in thickness between the walls of the ventricles. The formation of these muscular borders, and the general arrangement and direction of the muscular fibres at these parts, is examined. The fibres forming the walls of the ventricles converge around these apertures. The most superficial fibres may be traced up from the walls of the ventricles, curving obliquely over the convex border, and having their extremities, for the most part, fixed around the orifices. We may remove these fibres layer after layer, and still find the same arrangement to obtain, the deeper fibres lying more transversely and obliquely intersecting those above and below.

If now the auricles and great vessels which have been detached are replaced in their natural situation, it is observed that the auricles are connected with the *inner* surface of these convex borders, while the walls of the vessels pass down on to the outer surface. This fact is an important one when viewed in connection with the valves, and will be presently considered. In the mean time it may be remarked, that the formation of the auriculo-ventricular grooves in which the coronary vessels lie, is explained. These vessels are

found in the angle between the border of the ventricles and the wall of the auricles.

The nature of the fibrous zones or tendinous circles surrounding the orifices is examined. These rings are in especial relation with the valves, being closely connected with their attached bases, and are not such distinct and independent structures as they have been hitherto considered. After referring to some previous descriptions of the arterial tendinous rings, the author attempts to show that what has been described as the upper and thickened festooned border, is the result of the attachment of the bases of the valves to the arterial coat, and is formed by an intimate union of the fibrous tissue composing the valves with the elastic coat of the artery.

(1) These festooned borders correspond exactly with the attached bases of the valves, and hence their shape. (2) They are thickest and most strongly marked at the angle formed by the junction of two valves, to which point the bands of fibrous tissue in the valves converge. (3) The microscope shows these festooned rings to be composed of a mixture of the white fibrous with the yellow elastic tissue, an arrangement naturally to be expected from an intimate union of the tendinous tissue of the valve with the arterial coat.

The structure, connections and relations of the valves is examined chiefly by means of vertical sections carried through their centres and adjacent parts. Such sections of the arterial valves disclose an important relation which they have with the upper border of the ventricles. The aorta and pulmonary artery, expanding towards their termination, are situated upon the outer edge of the ventricular border before described; the consequence of which arrangement is, that the portion of valve adjacent to the vessel passes over and rests upon the muscular substance, and is supported upon the inner border of the free edge of the ventricles surrounding the arterial orifices. This arrangement, in consequence of the small size of the parts, is not so obvious at the first glance in the human heart, but is more strikingly shown in an examination of the heart of any one of the larger animals. This appears of importance when viewed in connection with the functions of the valves. The reflux of the blood is said to be sustained by the festooned rings at the base of the valves, but in fact they are thinnest at this very part, corresponding to the central portion of the convexity of the valves; and if the description previously given of the formation of the tendinous festooned rings be a correct one, it is obvious why it is so, the thicker portions being the projecting angle at the junction of two valves, to which points the tendinous fibres of the valves converge. Now, inasmuch as the posterior portion of the aortic orifice is continuous with the left auriculo-ventricular aperture, no muscular tissue of the ventricle existing at this part, the posterior aortic valve, and a portion of the adjacent one, have no support of this kind; but the muscular floor of the anterior aortic valve is especially broad, and it is the corresponding portion of the aorta which is particularly dilated, the posterior wall descending nearly vertically. The arrangement above described obtains in all three pulmonary valves; but as the border as well as the

walls of the right ventricle are considerably thinner than those of the left, the muscular floor of these valves is much narrower than in the anterior aortic valve. All this is of course seen on a much larger scale in the hearts of the larger animals, as the Horse and Ox; and here, where the muscular floor of the valves (more especially the anterior aortic) is of very considerable breadth, the tendinous tissue of the valve may be traced over the muscular surface to form the wall of the vessel.

In the larger Ruminants there are found two considerable portions of bone, partly surrounding the orifice of the aorta, and smaller irregular fragments are occasionally observed between the principal pieces. The larger portions vary much in size and shape in different hearts even of the same species. They are usually elongated and curved. The chief bone, which exceeds the other considerably in size, embraces the whole of the right side, and the right half of the back part of the orifice of the aorta; while the little bone, not generally found in the smaller Ruminants, as the Sheep, its place being occupied by a portion of dense fibrous tissue, extends from the middle of the left side round to the posterior part, where it more or less nearly joins the extremity of the larger bone. Thus the lateral and posterior portions of the aortic orifice are surrounded by firm bony arches meeting posteriorly in the centre. From the large bone, a small process usually passes backwards for some distance into the muscular substance of the septum between the ventricles, and is gradually lost in the dense fibrous tissue found in this part, surrounding the right border of the left auriculo-ventricular aperture; and from the convex surface of the smaller portion, a thin process of dense fibrous tissue is continued round the left margins of the auriculo-ventricular orifice. These heart-bones are intimately connected above with the middle coat of the aorta, on the inner surface with the base of the adjacent arterial valves, and posteriorly with the anterior mitral valve; while at the sides, to their external and inferior surfaces, the muscular fibres of the ventricle are attached. They may be seen and felt in the base of the pouches formed by the two posterior aortic valves, and no doubt greatly assist in sustaining the "force of the reflux." They occupy the position of the two posterior festoons of the aortic valves. In the human heart, in the situation corresponding to the position of these heart-bones, the tissue composing the festooned rings is thicker and denser than elsewhere, offering to the knife, in some cases, almost the resistance of bone. The processes of dense fibrous tissue found in the anterior portion of the border of the ventricular septum, &c., and extending round the right and left margins of the auriculo-ventricular orifice, are intimately connected with the thickened portions of the adjacent festoons.

Among the tissues entering into the structure of the arterial valves, elastic fibres are described. They exist not only in the corpus arantii, but delicate fibres of elastic tissue are found throughout the valve; most abundantly in the thicker portions, but even in the thinner portions (lunulæ) a few delicate but well-marked elastic

fibres may be seen, particularly after the addition of acetic acid, which of course assists greatly in bringing them into view.

Muscular fibres have not been found in the arterial valves.

The structure and connections of the auriculo-ventricular valves are next examined by means of vertical sections. In tracing down the muscular wall of the auricle, it is observed to pass on to the inner surface of the ventricular border, and if minutely examined is seen to terminate by two attachments. The external portion, which is considerably the larger, is closely connected with the fibrous structure forming the "auriculo-ventricular ring," while the thinner internal portion is continued forwards for a very short distance between the surfaces of the valve, and terminates more or less abruptly by an attachment to its tendinous tissue. This is generally best seen in one of the tricuspid valves, where, in a vertical section, the muscular fibres may be observed terminating beneath its upper surface immediately beyond its attachment to the ring. In the posterior mitral valve the muscular fibres seldom penetrate so far forwards, and this appears to result, when a section of the parts is examined, from the much greater thickness and density of the lining membrane of the left auricle.

The connections of the anterior mitral valve, being peculiar, require a separate consideration. In dissecting down between the anterior wall of the left auricle and the posterior surface of the aorta, it is seen that the central fibres of the auricular wall are closely attached to the adjacent wall of the vessel. A little further dissection on either side will show that the muscular substance of the left ventricle is deficient between these parts. At the sides indeed it is found, but is gradually lost at some distance from the mesial line. Hence these two orifices (the aortic and left auriculo-ventricular) are not separated as the others are by the intervention of the muscular fibres of the ventricle. The structure and connections of the anterior mitral valve are examined by means of a vertical section, including the posterior wall of the aorta and the anterior wall of the left auricle. If the lining membrane of the auricle be traced downwards, it is found to be directly continued on to the posterior surface of the valve, and the membrane on the anterior surface of the valve is continued upwards over the tendinous festooned ring of the aorta, on to the under surface of its semilunar valves. The anterior mitral valve lies beneath a portion of the two posterior arterial valves. The muscular wall of the auricle is observed to terminate by two distinct insertions. The anterior (the larger) division of fibres is attached to the posterior surface of the aorta, opposite to, and below the festooned ring, while the posterior portion is continued directly downwards for a short distance into the valve, and terminates by an attachment to its fibrous tissue. The posterior wall of the aorta descends nearly vertically. Suddenly becoming much thinner opposite the upper border of the semilunar valve, it is continued down to the festooned ring, or in other words, it here becomes blended with the base of the semilunar valves. Below this a dense layer of fibrous tissue (which exists below, and fills up the spaces between

the attached bases of the semilunar valves) descends for some distance into the anterior mitral valve, immediately behind its anterior surface. It is by a close attachment to the posterior surface of this layer that the muscular fibres of the auricular wall which descend into the valve, terminate. This layer of fibrous tissue, however, may be generally traced downwards into the valve farther than the muscular fibres.

The boundary, then, between the aortic and auricular apertures is formed above the mitral valve by the posterior wall of the aorta, terminating at its junction with the bases of the semilunar valves, and immediately below the posterior surface of which is attached the greater portion of the muscular fibres forming the anterior wall of the left auricle. The extremities of the two bones which in ruminants replace a portion of the lateral and posterior divisions of the "festooned ring," nearly meeting in the centre, behind, give additional support to the structures entering into the formation of the mitral valve.

In examining the structure and connections of the auriculo-ventricular valves, it is noticed that a considerable portion of tendinous fibres pass from the insertions of the cords, through the valves, to the zones, and many of the smaller cords pass up directly into the angle formed between the under surface of the valve and the inner surface of the ventricle, and at once enter into the formations of the fibrous zones. These cords are short, and many of them spring from the wall of the ventricle, behind the valve. Therefore it results, that these zones are densest and most strongly marked in those portions corresponding to the attached borders of the valves, and gradually become less distinct towards the intervals between them. Hence the greater portion of the auriculo-ventricular zones is more properly to be considered in connection with the valves.

The fibres of elastic tissue exist in the auriculo-ventricular valves, but more sparingly than in the arterial valves.

The many contradictory statements which have been advanced concerning the existence of muscular fibres in the auriculo-ventricular valves, may perhaps be explained by a consideration of the mode in which the muscular fibres of the auricles terminate, which has been already described. The internal fibres which have been mentioned, descending from the auricular walls into the valves just beyond their attached margins, may be traced to a greater distance in some cases than in others. They generally terminate by a tolerably well-defined margin, but this varies. They usually descend for a greater distance between the layers of the anterior mitral valve, immediately beneath its auricular surface; but even here they are seldom found stretching far into the valve, not terminating, however, so abruptly.

Therefore, if a portion of the attached border of a valve immediately below its upper surface be examined, muscular fibres in abundance will generally be detected; whereas if sought for in any other portion of the valve far from its attached border, according to the foregoing observations, they will not be found.